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# Effect of the Bioactivator Application on Fruit Quality Under Different Irrigation Regime in 'Kabarla' Strawberry Variety

**Mehmet Ali Sarıdas[1, *], Sevgi Paydas Kargi[1], Burcak Kapur[2], Eser Celiktopuz[2]**

[1]Department of Horticulture, Faculty of Agriculture, University of Çukurova, Adana, Turkey

[2]Department of Agricultural Structures and Irrigation Engineering, Faculty of Agriculture, University of Çukurova, Adana, Turkey

## Email address:

masaridas@gmail.com (M. A. Sarıdas)

[*]Corresponding author

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**Abstract:** Strawberry quality is mostly affected by cultural application such as irrigation and fertilization. In this study, beside of full irrigation (IR100); 50% (IR50), 75% (IR75) and 125% (IR125) were performed different level by drip irrigation. Also, bio-activator which named Comcat, is produced from seaweed and special wild plant. Applications were applied additional with irrigation levels. Their effects on fruit quality such as fruit size (diameter, length and weight), TSS, acidity, pH and ratio of TSS (Total Soluble Solid) with titratable acidity were investigated during active harvest period (March-May). As a result of this study, fruit size was completely determined by the growing period. All fruit size (diameter, length and weight) was found the lowest in May due to increasing temperature and decreasing plant vigor. While the Bio-stimulant application negativity affected the TSS content, the IR50 irrigation regime was increased statistical significantly. Application and irrigation regimes not influenced pH value; however, it was increased throughout progressive harvest period from 3.45 (April) to 3.78 (May). Sugar/acid ratio was statistical significant level increased with progressive harvest time and by lowered water supply. The highest sugar/acid ratio was found in May at IR50 plot with 19.3 value. Also, the results were related to correlation analyses. While the fruit size parameters were positively correlated with each other, these parameters were negatively correlated with pH and TSS which affected the eating quality.

**Keywords:** Eating Quality, Sugar/Acid Ratio, Water Levels

## 1. Introduction

The production of strawberries (Fragaria X ananassa Duch.) has increased by 23% globally and by 25% in Turkey from 2010 to 2014. Strawberry production mainly occurs in Mediterranean region where includes Adana province [7]. This fruits highly demanded by consumers by good organoleptic properties and phytochemical content [3]. Although the choosing best suitable cultivar was very important factor to occurring high organoleptic properties [15, 23], cultivation management is also important to get more healthy-related compounds and to improve fruit quality by providing suit irrigation amount and fertilization [11, 16]. Deficient irrigation is not only increasing the taste-related compounds, but also provides to efficiently use water reserve. As a report of UNESCO, one-third of the world's population lives under the water scarcity condition, and it is foreseen that this will reach over two-thirds in 2025 [30]. Agricultural water usage is positively correlated by world population growth, and water management is not easy by farmers. They make use of past experience to determine optimal irrigation water amount by observation of weather conditions and visual plant indicators of stress. However, growers tend to use excessively or inadequately supplied water, which can have a negative impact on vegetative part and fruit size [8, 20]. On the contrary, reducing water irrigation between flower initiation and fruit harvest may be good strategy for improving the health-related compounds and concentrating of taste-related compounds [18, 15].

Another important objective is to breeding new strawberry cultivar which has higher crop water use efficiency which being less affected by deficient irrigation [22]. Beside of different irrigation levels, some pre-harvest application is applied to increasing health-related compound [16]. Bio-stimulants have been gaining interest for sustainable agriculture because their application enables several physiological processes that increase nutrient use efficiency, encouraging plant development and allowing the reduction of fertilizers consumption [6, 25].

The objectives of this study were: (1) to determine the effect of different irrigation level and bio-stimulant application on fruit size and quality parameters such as TSS, acidity, pH and sugar/acid ration at the 'Kabarla' strawberry variety during the active harvest period (March-May). (2) to determine the best harvesting time with suitable irrigation and application combination on all observed parameters.

# 2. Materials and Methods

The field experiment was conducted inside the high tunnel at the experimental farm of the Çukurova University (latitude: 36°59'9N, longitude 35°27'7E and altitude 20 m above sea level). The soils at the site were classified as heavy clay texture [19] and the soil water content at field capacity and permanent wilting point are 34 g/g and 18 g/g respectively. Strawberries (*Fragaria Xananassa* Duch. Kabarla cv.) were planted on November 10 in 2015 and harvesting continued till June 8 in 2016.

The berries were planted in trapezoidal raised beds measuring 0.70 m from the base, 0.50 m at the top, with a height of 0.30 m. The distance among each bed was 0.4 m and covered by 0.05 mm thick two-sided polyethylene mulch cover with a grey upper side and black under side according to the conventional cultural practices in the area. After planting, equal amount water was applied to all treatments until the plants were reached 3 trifoliate (28 January). Fertilizer was applied uniformly to all treatments during the trial through drip irrigation and foliar spraying. Plant protection was carried out by controlled with timely spraying of agricultural pesticides.

The trail was implemented as a 4×2 factorial scheme (irrigation levels and bio-stimulant use), in split plot design with 3 consequent months at 3 replicates, totally 24 plots. Bio-stimulant applications were designed as main plot and different irrigation levels were arranged as sub plot. Strawberry plant was subjected to four irrigation water levels as Ir50, Ir75, Ir100, Ir125 in which the water quantities applied were 0.5, 0.75, 1.00 and 1.25 times the pan evaporation measured by the US Weather Service Class A pan with a standard 120.7 cm diameter and 25 cm depth placed over the crop canopy in the center of the high tunnel.

The content of the bio-stimulant which was named ComCat was certified by the BCS Öko-Garantie GMBH, Nurnberg, Germany as seaweed extract; organic matter (67%), $K_2O$ (1.5%), alginic acid (18%) and gibberellic acid (250 ppm). The bio-stimulant was applied as foliar spraying on strawberry four times. The amount applied at each treatment was 40 gr extract in 30 L water $da^{-1.}$

Irrigation water (salinity 0.18 dS/m) was applied using the drip tube with emitters spaced every 0.3 m, with a flow rate of 2.7 l $h^{-1}$ and the amount of irrigation water was calculated by using Eq (1).

$$t = (A \times Ep \times Pc \times Kcp) / (q \times n) \quad (1)$$

where, t is the irrigation time (hours), A the area of plot ($m^2$), Ep the cumulative free surface water evaporation at irrigation interval (mm), Pc the plant cover (%), Kcp the crop-pan coefficient which is taken 0.7 throughout the trial as mentioned in [26], q the flow rate of emitters and n the number of emitters in the plot.

All observations were conducted during the active growing period by monthly (March-May). The physical analysis included the fruit diameter, length as measured by a digital caliper, and fruit weight measured by precision scales (KERN PCB Germany) (0.1 g). Three replicates and 30 fruits in each replicate were used for detection of pomological analysis such as total soluble solids, titratable acidity, pH and sugar/acid ratio. Total soluble solids in fruit juice of each genotype were determined by a hand type refractometer (ATAGO ATC-1, Tokyo, Japan). Titratable acidity (g malic acid 100 $mL^{-1}$) was measured by titrating with 0.1 N NaOH to pH 8.10. Samples of juice for pH were measured by pH meter (Mettler Toledo USA). Sugar/acid ratio was obtained by dividing the TSS to the total acid amount.

The experiment was conducted as two factors randomized complete block design with split plot combined with active harvest month with three replications. The obtained data were analyzed with the statistical program JMP version 5.0.1 (SAS Institute Inc., Cary, NC). ANOVA was carried out to determine the effects of the different irrigation regime and bio-stimulant application at active growing period monthly on examined pomological parameters. A least significant difference test was done to examine the differences among groups. Comparisons that yielded $P \leq 0.05$ were considered to be statistically significant. In addition, correlation among all the obtained results was carried out through multivariate methods with the statistical program JMP version 5.0.1, with $P \leq 0.05$ as threshold.

# 3. Results and Discussion

The result of fruit physical and weight properties were given Table 1. According to our finding, all parameters were not influenced statistical significantly from any examined factors except to harvesting period. It is well known that fruit quality and weight are decreased by progressive growing period than ones that mature later [13]. Similarly, [12] reported that the decreased at the fruit weight until to the end of harvested period in all examined cultivars. They also measured mean fruit weight ranged between 14.86 g (Clery cv.) and 22.06 g (Asia cv.) which included all data except May measurements. Fruit weight was similar between March and April; it sharply decreased

with progressive growing period. The lowest fruit weight and size were measured in May due to decreasing plant vigor and increasing temperature which cause shortened fruit growing time. Similarly with [9] fruit weight was not significantly affected by different irrigation regimes at different soil condition. However, marketable fruit significantly increased with application of irrigation treatment. While applied deficient irrigation in strawberry plant total yield and berry number were decreased. However, statistical level of the average fruit weight was not changed like as our finding [5] correlatively, [21] were determined decreased on marketable yield. They also found to decrease berry weight with lowered water. However, the reaction of cultivar to the deficient irrigation was found varied in terms of marketable yield and berry weight.

***Table 1.*** *Effect of the different irrigation regimes and bio-stimulant application on fruit diameter, length and weight during the active harvest period.*

| | Irrigation | Application | Harvest Period | | | Irr X App | Irr Av. |
|---|---|---|---|---|---|---|---|
| | | | March | April | May | | |
| Fruit Diameter (mm) | IR50 | Control | 32.5 | 34.9 | 28.4 | 31.9 | 31.4 |
| | | Comcat | 32.6 | 32.5 | 27.5 | 30.9 | |
| | IR75 | Control | 32.9 | 33.3 | 31.4 | 32.6 | 32.3 |
| | | Comcat | 31.9 | 34.4 | 29.6 | 31.9 | |
| | IR100 | Control | 32.5 | 35.7 | 28.3 | 32.2 | 31.5 |
| | | Comcat | 31.4 | 32.5 | 28.8 | 30.9 | |
| | IR125 | Control | 30.7 | 31.7 | 31.7 | 31.4 | 30.9 |
| | | Comcat | 30.0 | 32.5 | 28.9 | 30.5 | |
| | Period Av. | | 31.8 B | 33.5 A | 29.3 C | | |
| LSDper*** = 1.41 | | | | | | | |
| | **Irrigation** | **Application** | **March** | **April** | **May** | **Irr X App** | **Irr Av** |
| Fruit Length (mm) | IR50 | Control | 39.8 | 33.2 | 27.1 | 33.4 | 33.1 |
| | | Comcat | 37.5 | 32.2 | 28.7 | 32.8 | |
| | IR75 | Control | 41.1 | 31.7 | 32.0 | 34.9 | 34.6 |
| | | Comcat | 39.3 | 33.4 | 30.1 | 34.3 | |
| | IR100 | Control | 39.1 | 32.3 | 28.6 | 33.3 | 32.9 |
| | | Comcat | 38.7 | 30.5 | 28.2 | 32.5 | |
| | IR125 | Control | 38.7 | 31.9 | 32.4 | 34.3 | 34.0 |
| | | Comcat | 37.4 | 32.6 | 31.1 | 33.7 | |
| | Period Av. | | 38.9 A | 32.2 B | 29.8 C | | |
| LSDper*** = 1.88 | | | | | | | |
| | **Irrigation** | **Application** | **March** | **April** | **May** | **Irr X App** | **Irr Av** |
| Fruit Weight (g) | IR50 | Control | 20.7 | 20.9 | 10.8 | 17.5 | 16.7 |
| | | Comcat | 17.0 | 17.6 | 13.2 | 15.9 | |
| | IR75 | Control | 19.2 | 18.2 | 15.9 | 17.8 | 17.2 |
| | | Comcat | 18.2 | 18.6 | 12.9 | 16.6 | |
| | IR100 | Control | 18.0 | 19.8 | 11.4 | 16.4 | 15.9 |
| | | Comcat | 17.4 | 16.9 | 11.8 | 15.3 | |
| | IR125 | Control | 17.1 | 16.7 | 16.9 | 16.9 | 16.0 |
| | | Comcat | 14.9 | 17.0 | 13.5 | 15.2 | |
| | Period Av. | | 17.8 A | 18.2 A | 13.3 B | | |
| LSDper*** = 1.81 | | | | | | | |

(1). Differences between the means were showed with different letters
(2). N. S.: Not Significant, ***: p<0.001; **: p<0.01; *: p<0.05

Table 2 shows some pomological properties that affect the fruit quality under the different irrigation regimes on 'Kabarla' cultivar with bio-stimulant application during the active harvest period, such as TSS, acidity, pH and sugar/acid ratio. Bio-stimulant application was not influenced the pH and sugar/acid ratio. While the acidity was decreased by application, TSS content found higher at the control plant. The deficient irrigation (IR50) was significantly increased the TSS content and sugar/acid ratio which affect the fruit taste and acceptability by consumer.

***Table 2.*** *Effect of the different irrigation regimes and bio-stimulant application on fruit pomological properties during the active harvest period.*

| | Irrigation | Application | Harvest Period | | | IrrXApp | Irr. Av. |
|---|---|---|---|---|---|---|---|
| | | | March | April | May | | |
| TSS (%) | IR50 | Control | 6.10 hij | 8.43 bcd | 8.83 ab | 7.79 | |
| | | Comcat | 5.97 hij | 7.83 cde | 8.53 bc | 7.44 | 7.62 A |
| | Irr x Per | | 6.03 E | 8.13 BC | 8.68 A | | |
| | IR75 | Control | 5.43 j | 7.73 de | 9.33 a | 7.50 | |
| | | Comcat | 5.33 j | 7.63 e | 7.83 cde | 6.93 | 7.22 B |
| | Irr x Per | | 5.38 F | 7.68 CD | 8.58 AB | | |
| | IR100 | Control | 6.50 gh | 7.37 ef | 7.83 cde | 7.23 | 7.09 B |
| | | Comcat | 5.67 ij | 7.77 cde | 7.40 ef | 6.94 | |

| | Irrigation | Application | Harvest Period | | | IrrXApp | Irr. Av. |
|---|---|---|---|---|---|---|---|
| | | | March | April | May | | |
| | Irr x Per | | 6.08 E | 7.57 D | 7.62 CD | | |
| | IR125 | Control | 6.73 fgh | 7.90 cde | 7.17 efg | 7.27 | |
| | | Comcat | 6.33 hi | 7.30 ef | 7.67 de | 7.10 | 7.18 B |
| | Irr x Per | | 6.53 E | 7.60 CD | 7.42 D | | |
| | Period Av. | | 6.01 C | 7.75 B | 8.08 A | | |
| LSDper*** = 0.27 LSDapp** = 0.22 LSDirr** = 0.32 LSDirrxper*** = 0.55 LSDappxirrxper* = 0.77 | | | | | | | |
| | **Irrigation** | **Application** | **March** | **April** | **May** | **Irr X App** | **Irr Av.** |
| | IR50 | Control | 0.46 | 0.74 | 0.48 | 0.56 B | |
| | | Comcat | 0.51 | 0.67 | 0.45 | 0.54 B | 0.53 |
| | Irr x Per | | 0.49 DE | 0.71 A | 0.46 E | | |
| | IR75 | Control | 0.47 | 0.54 | 0.55 | 0.52 B | |
| | | Comcat | 0.48 | 0.61 | 0.53 | 0.54 B | 0.53 |
| | Irr x Per | | 0.47 | 0.57 BC | 0.54 CD | | |
| Acidity (%) | IR100 | Control | 0.51 | 0.63 | 0.51 | 0.55 B | |
| | | Comcat | 0.51 | 0.49 | 0.55 | 0.52 B | 0.53 |
| | Irr x Per | | 0.51 CDE | 0.57 BC | 0.53 CDE | | |
| | IR125 | Control | 0.56 | 0.72 | 0.61 | 0.63 A | |
| | | Comcat | 0.51 | 0.52 | 0.54 | 0.53 B | 0.58 |
| | Irr x Per | | 0.54 CD | 0.62 B | 0.57 BC | | |
| | Period Av. | | 0.50 B | 0.62 A | 0.53 B | | |
| LSDper*** = 0.027 LSDapp* = 0.031 LSDirrxper*** = 0.075 LSDappxper* = 0.053 LSDirrxapp* = 0.062 | | | | | | | |
| | **Irrigation** | **Application** | **March** | **April** | **May** | **Irr X App** | **Irr Av.** |
| | IR50 | Control | 13.3 | 11.6 | 18.7 | 14.6 | |
| | | Comcat | 11.6 | 11.9 | 19.9 | 14.5 | 14.5 A |
| | Irr x Per | | 12.5 CDE | 11.8 DE | 19.3 A | | |
| | IR75 | Control | 11.7 | 14.4 | 17.2 | 14.4 | |
| | | Comcat | 11.0 | 12.7 | 14.7 | 12.8 | 13.6 AB |
| | Irr x Per | | 11.4 E | 13.5 CD | 15.9 B | | |
| Sugar/acid | IR100 | Control | 12.7 | 11.8 | 14.7 | 13.3 | |
| | | Comcat | 11.2 | 15.6 | 13.6 | 13.5 | 13.4 AB |
| | Irr x Per | | 11.9 DE | 13.7 CD | 14.5 BC | | |
| | IR125 | Control | 12.1 | 11.4 | 11.8 | 11.8 | |
| | | Comcat | 12.4 | 13.9 | 14.2 | 13.5 | 12.6 B |
| | Irr x Per | | 12.2 DE | 12.7 CDE | 13.0 CDE | | |
| | Period Av. | | 11.9 B | 12.9 B | 15.7 A | | |
| LSDper*** = 1.01 LSDirr* = 1.17 LSDirrxper*** = 2.02 | | | | | | | |
| | **Irrigation** | **Application** | **March** | **April** | **May** | **Irr X App** | **Irr Av.** |
| | IR50 | Control | 3.53 | 3.45 | 3.80 | 3.59 A | 3.55 |
| | | Comcat | 3.32 | 3.43 | 3.76 | 3.50 B | |
| | IR75 | Control | 3.42 | 3.51 | 3.79 | 3.58 A | 3.59 |
| | | Comcat | 3.45 | 3.63 | 3.76 | 3.62 A | |
| pH | IR100 | Control | 3.46 | 3.56 | 3.83 | 3.62 A | 3.60 |
| | | Comcat | 3.47 | 3.54 | 3.77 | 3.59 A | |
| | IR125 | Control | 3.43 | 3.53 | 3.71 | 3.56 AB | 3.59 |
| | | Comcat | 3.50 | 3.57 | 3.78 | 3.62 A | |
| | Period Av. | | 3.45 C | 3.53 B | 3.78 A | | |
| LSDper*** = 0.038 LSDirrxapp** = 0.062 | | | | | | | |

(1): Differences between the means were showed with different letters
(2): N. S.: Not Significant, ***: p<0.001; **: p<0.01; *: p<0.05

Deficient irrigation is a new strategy to improve not only fruit taste related compound, but also increased water use and water use efficiently [15, 28]. In addition to this, bio stimulant application is became a common practice in sustainable agriculture due to reducing fertilizers and other chemical compound application [26]. According to [12], bio stimulant plays an important role against the late spring frosts and improving fruit weight. Results showed significant differences between applications, irrigations, harvesting time and interaction between irrigations and harvesting time regarding TSS content. While the highest (7.62%) TSS content was found IR50 plot, application was negatively affected of this content. Thank to statistical significant interaction among all examined factors, it provide an opportunity to increase of TSS content with different way. The fruit taste is not only determined by sugar content. Acids and volatile compounds are also valuable contributors to taste and flavor [4]. In this study, while the acidity was statistically decreased by applications. Irrıgation amount was not influence the fruit acidity. The interaction of irrigation with harvesting time and application was found statistically significant. While the highest acidity was found in the control plant where taken place in IR125 plot, all the others take same statistical group [29] reported that effect of moisture status of soil on titratable acidity. However, in our experiment couldn't found any relation in the fruit acidity at

the different irrigation regimes. The balance between sugars and acids are important indicators of fruit taste [14]. The TSS/acidity ratio, which is often used as an index of fruit ripeness for taste and consumer acceptance [1, 2], was increased with lowered irrigation. The highest ratio was determined IR50 plot last harvesting time (May). The pH value mainly is affected by harvesting time. It was increased from 3.45 (March) to 3.78 (May) with progressive harvesting time.

***Table 3.*** *Correlation coefficients of several fruit quality and fruit size properties at different irrigation regime with bio-stimulant application during active growing period. (P ≤ 0.05).*

| Trait | v2 | v3 | v4 | v5 | v6 |
|---|---|---|---|---|---|
| Fruit Diameter (v1) | 0.51* | 0.87* | - 0.13 | -0.39* | 0.27* |
| Fruit Length (v2) | | 0.72* | - 0.70* | -0.58* | -0.15 |
| Fruit Weight (v3) | | | -0.32* | -0.51* | 0.17 |
| TSS (v4) | | | | 0.58* | 0.30* |
| pH (v5) | | | | | -0.13 |
| Acidity (v6) | | | | | 1 |

*Significant coefficients, at 0.05, are shown in bold.

The results of correlation showed that most of the variables were significantly correlated with each other (Table 3). The size of variables (fruit width, length, and weight) was all positively correlated with each other. The quality parameters such as TSS and pH is shown negatively correlated by fruit size parameter. The means of this result, increasing fruit size is deteriorated fruit taste by affected TSS and pH. At the study by conducted [17], were reported C vitamin content ranged 64.4-104.3 mg/100g, also found higher sugar were found the cultivar which has low C vitamin. Researchers have found a negative correlation between sugar and acidity with progressive ripening; as the sugar content increases, the acidity decreases [10, 31]. Similarly, [24], determined the negative correlation (-0.906) each other. Interestingly, the relation was found positive between acidity and TSS in this study.

# 4. Conclusions

Deficient irrigation strategy was very useful for increasing taste-related compound such as TSS and TSS/Acidity without any decreasing on fruit size and weight. Also, fruit acidity could be decreased by applying bio stimulant. The all quality parameters were influenced by harvesting time and were found a negative correlation between bigness of fruit (fruit diameter, length and weight) and taste related (TSS and acidity) properties. Thank to statistical significant interaction among all examined factors, it provide an opportunity to increase of TSS content with different way.

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